



SPACE SHUTTLE PROGRAM

NASA Kennedy Space Center, Florida



Fondu Fyre Historical Liberation (Action Response for Debris Integration Group) (DIG)

Engineering Review Board (ERB) 8/05/08

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- "Unexpected" classification of Fondu Fyre in Hazard LL-0077
- Description of KSC efforts to mitigate Fondu Fyre liberation
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- Recommendation

Also submitted as a separate attachment:

- Steve Koca PRCB pitch on Fondu Fyre from 2/22/07.



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Fondu Fyre Action/Objective

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Action:

The 7/16 Debris Integration Group (DIG) assigned an action to Launch & Landing to provide the following:

- Historical liberation data for Fondue Fyre
- Information about dent on underside of MLP-3
- Information on STS-83 report of Fondu Fyre found on MLP deck
- Explanation of "Unexpected" classification of Fondu Fyre in Hazard LL-0077

Objective:

To obtain ERB recommendations/redlines and concurrence to present the following information to the 8/13 Debris Integration Group (DIG) for action closure.



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Historical Data Sources

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The following historical data on Fondu Fyre liberation has been gathered from several sources:

- The historical data from repair documentation was compiled by USA Structures Engineering. (Mainly Problem Reports)
- The Post-Launch Debris Walk-down data and film review data (from S6444) was originally written by the Debris & Ice Team, and filtered for Fondu Fyre events by MSFC.
- The S2005 Post-Launch Systems walk-downs were originally built into a Historical Debris Database for RTF which was filtered for refractive liberation information.



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History Derived from Repair Documentation

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DATE	STS	PAD	EXTENT OF DAMAGE
4/21/1981	1	A	Lost Bricks from Flame Trench Floor Near SRB MFD. Size of areas where bricks lost approx. 10' x 3', 5' x 6", 3' x 6" and 3' x 6"
4/21/1981	1	A	Wall Cap damage
1/12/1982	2	A	Lost Bricks from Flame Trench Floor.
9/7/1983	8	A	Replace portion of refractory concrete of SRB/SSME MFD during STS-10 downtime
8/5/1985	26	A	SRB MFD some erosion and small chip in upper west portion increased in size
5/13/1986	51L	B	Approx. 34' x 7' area of bricks lost 120' North of the MFD.
12/12/1988	27	B	SRB MFD missing section of Fondue-Fyre 8' from trench wall
9/1/1989	61C	A	Cracks in MFD. Cracks in SFD
2/28/1990	36	A	SRB MFD lower west lip
10/17/1990	41	B	SRB MFD and Trench wall damaged during launch. Refractory and grid steel is damaged in various places. Surface appears heavily eroded on approx. 20 percent and is cracked or raised in various places
12/7/1990	35	B	SRB MFD and Trench Wall are damaged/missing in various places
4/15/1991	37	B	SRB MFD and Trench Wall damaged grid steel and refractory.
4/28/1991	39	A	SRB MFD 12 sq. ft. on east lip and 25 sq. ft. on west lip of Fondue-Fyre missing
4/30/1991	39	A	SRB MFD and Trench Wall damaged grid steel and refractory.
6/7/1991	40	B	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing



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DATE	STS	PAD	EXTENT OF DAMAGE
8/2/1991	43	A	Approx. 20% Fondue-Fyre missing. SRB MFD lower lip East and West side, upper east lip
8/5/1991	43	A	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing
9/17/1991	48	A	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing
11/25/1991	44	A	Concrete and Grid steel missing/damaged; 4' x 8' lower east on MFD, 2' x 4' 2 places on lower west side MFD, 1' x 2' upper west side MFD, lower lip on both side flame deflectors.
11/25/1991	44	A	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing
1/22/1992	42	A	SRB MFD west side 6' x 10' missing at lip. SRB MFD east side 8' x 10' missing at lip.
1/23/1992	42	A	SRB MFD refractory and grid steel damaged/missing in various places
1/23/1992	42	A	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing
4/10/1992	45	A	SSME and SRB MFD and Trench Wall damaged. Refractory damaged/eroded exposing grid steel.
6/26/1992	50	A	SRB MFD and Trench Wall damaged grid steel and refractory. Grid steel and refractory missing
8/3/1992	46	B	SRB MFD Damage. 2 small chunks of Fondue-Fyre were blasted off.
9/14/1992	47	B	SRB MFD Fondue-Fyre missing along lip under the east SRB Exhaust Hole
10/26/1992	52	B	Wall Cap Along the North end of Flame Trench is crumbling in Various Places.



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DATE	STS	PAD	EXTENT OF DAMAGE
12/3/1992	53	A	MFD Fondue-Fyre missing in various places on both SSME and SRB sides.
4/15/1993	56	B	SRB MFD refractory concrete damaged.
4/28/1993	55	A	East SFD pieces missing at lower lip. SRB MFD Fondue-Fyre and grid steel torn away at east side bottom lip 10' x 20', SSME MFD (qty. 3) 1' x 3' pieces missing
6/22/1993	57	B	SRB MFD refractory concrete missing along lip.
9/14/1993	51	B	Section of the lower steel lip of the East SFD was blown off during launch
9/14/1993	51	B	SRB MFD refractory concrete missing along flame fence at the lower west corner
10/19/1993	58	B	SRB MFD refractory concrete and grid steel missing along the lower east lip and the east flame fence.
12/2/1993	61	B	Minor damage along lower east lip of MFD, missing 3' x 3' and 1' x 2' sections of concrete
12/2/1993	61	B	SRB MFD Fondue-Fyre damaged during launch along lower east lip. East side flame trench wall cap damaged.
2/3/1994	60	A	minor cracking/missing concrete on Side Flame Deflector
2/7/1994	60	A	East SFD Fondue-Fyre missing in various locations
7/8/1994	65	A	4 bricks missing from north end of flame trench SSME MFD 4' x 4' eroded grid steel and 4 cracks 4' long x 2" wide, East Side Flame Deflector chips 4" x 4" in 2 places
7/13/1994	65	A	West SFD SRB side damaged or missing Fondue-Fyre along lower lip. SSME MFD damaged or missing Fondue-Fyre at center. East side wall cap damage. Damaged Fondue-Fyre along Flame Trench Floor and west Side Flame Trench Wall



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DATE	STS	PAD	EXTENT OF DAMAGE
9/12/1994	64	B	SRB MFD damaged/missing Fondue-Fyre along east side lower lip. East side wall cap damaged
9/30/1994	68	A	SSME Flame Trench Wall Cap Damaged
11/3/1994	66	B	SRB MFD missing area midway up west side and along the lower east side
11/8/1994	66	B	SRB MFD damage midway up west side and along east side lip
6/25/1995	50	A	8' x 12' missing ablatives beneath west SRB hole. 10' x 15' missing ablatives beneath east SRB hole. Cracks along lower lip of east SFD.
6/27/1995	71	A	SRB MFD grooves and depressions on lower east end
7/13/1995	70	B	SRB MFD missing 3' x 3' area along lower east lip and cracked midway up on the westside
9/7/1995	69	A	North Flame Trench Floor buckled, SRB MFD minor cracking along east lip
2/24/1996	75	B	SRB MFD 2' x 3' chip, North Flame Trench Floor 1' x 2' piece missing
6/27/1996	78	B	SFD Damage
2/14/1997	82	A	MFD damage 2 sq. ft. east side lower lip, 1 sq. ft. west side lower lip, 2 sq. ft. east side approx. 8' below top
5/18/1997	84	A	SRB MFD chip missing 10' from bottom and 15' from west side and crack 3' from bottom 5' from west side
7/25/1997	94	A	SRB MFD damage along west side lower lip. SSME MFD 1.5' x 3' and 1.5' x 2' damage just east of centerline
8/12/1997	85	A	Loose and cracked Fondue-Fyre SRB MFD and SSME MFD
9/2/1997	85	A	SSME south slope crack 5' x 3' located 7' down from top edge and 8' from east side
9/2/1997	85	A	West SFD missing 8' x 8' along bottom starting at center and running south



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DATE	STS	PAD	EXTENT OF DAMAGE
12/8/1997	86	A	SRB MFD approx. 25 sq. ft. of Fondu-Fyre needs repaired. Loose bricks on 2nd seam south of SSME MFD lip 25' above floor of trench
2/13/1998	89	A	MFD damage north and south
2/13/1998	87	B	SRB MFD 1 sq. ft. chip on lip 6 ft. from east edge and 2' x 4' chip 8' from the west and 12' above the lip
2/19/1998	89	A	West SFD missing 8' x 6' starting at center and running south and 8' x 2' starting 1' from north end and running south
12/3/1998	95	B	SRB MFD crack on seam approx. 30' long. SSME MFD 4.5' x 3' damage at bottom of slope
7/25/1999	93	B	SRB MFD west side 2' x 3' missing at lip. SRB MFD east side 3' x 5' missing at lip.
8/24/1999	93	B	MFD damage on/near lower lip at 3 places, corner chip on east wall above the lip, and area of recent repair on the west wall.
2/11/2000	99	A	Loose refractories in Flame Trench
2/8/2001	98	A	SSME MFD some loss of refractory. SRB MFD some loss of refractory. Flame trench minimal loss of refractory and exposed grid steel
3/8/2001	102	B	SRB MFD general erosion; 60" x 2' repair and 8' x 3' repair in NE corner
4/19/2001	100	A	SRB MFD some loss of refractory. SRB Flame Trench growing amount of exposed grid steel.
7/12/2001	104	B	SRB MFD approx. 40 sq. ft. of repairs needed in 11 different areas. Approx. 34" x 51" of refractory lost and grid steel eroded.
10/8/2002	112	B	SRB MFD right side: 4' x 6' chip at lip and 4' x 4' approx. 15 ft up slope. SRB MFD left side: 3' x 4' at lip and 3' x 10' with missing Grid steel and studs approx. 6' up slope. Flame Trench floor has exposed grid steel 3' x 4' in several places.



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DATE	STS	PAD	EXTENT OF DAMAGE
8/4/2005	114	B	MFD lost some Fondu-Fyre
5/23/2006	115	B	SRB MFD very minor damage. Loose flat sized piece of refractory on west fence.
7/5/2006	121	B	Loose bricks on east flame trench wall
7/6/2006	121	B	SRB MFD missing upper S.W. corner
9/13/2006	115	B	East Flame Trench Wall minor spalling of Refractory adjacent to MFD
11/11/2006	118	B	SSME MFD some existing exposed grid steel
8/12/2007	117	A	minor damage to MFD
8/14/2007	118	A	East Side North Trench Wall Cap lost some Fondu-Fyre
8/14/2007	118	A	No major damage/anomalies. Some loose refractory was removed.
8/17/2007	118	A	SSME flame trench wall loose & missing bricks.
10/23/2007	120	A	SRB MFD Fondu-Fyre lost in several locations.
10/24/2007	120	A	SRB MFD missing Fondu-Fyre
2/13/2008	122	A	SRB MFD very minor damage. A 12" x 12" area in the upper east section may have delaminated. A smaller area 6" x 4" liberated.
3/13/2008	123	A	East Side Wall Fillet above MFD Flame Fence refractories liberated approx. 3' x 12'. West Side Wall Fillet 3' x 3'
6/4/2008	124	A	West SFD lost 6' x 8' x 12" piece of Fondu-Fyre
6/4/2008	124	A	East Flame Trench Wall approx. 2000 sq. ft. of brick liberated



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Fondue Fyre History From Post-Launch Data (S6444, S2005, Film Review)

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STS	PAD	DESCRIPTION
29R	B	A PIECE OF DEBRIS RISES OUT OF THE FLAME TRENCH AFTER THE VEHICLE HAS CLEARED THE MLP. (film review)
30R	B	The west lip of the SRB side flame deflector was missing a piece 3'x1'. No evidence of this debris was found on the pad acreage and the piece may have disintegrated as it was pulled loose from the reinforcing metal lattice of the flame deflector surface
33R	B	OBJECT LEADS THE SRB EXHAUST PLUME OUT OF THE FLAME TRENCH AT GMT 00:23:32.918. (film review)
36	A	Several pieces of facility debris were scattered to the pad perimeter. The most significant facility debris was large pieces of flame deflector found in the flame trench and north field.
37	B	Comments: A dark particle appeared in the flame trench north of the MLP (film review) Three particles were ejected out of the north flame trench.
39	A	Main Flame Deflector north side a 12 square foot section of fondue fire is missing on the east side lip.
40	B	Combined comments: A minimum of 4 dark/long particles appeared against the horizon after being ejected out of the SRB flame trench.
41	B	Particle rising vertically out of exhaust hole as vehicle clears frame does not contact vehicle.



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Fondue Fyre History From Post-Launch Data (S6444, S2005, Film Review)

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STS	PAD	DESCRIPTION
42	A	ABLATIVE AND GRID STEEL MISSING ON LOWER LIP OF MAIN FLAME DEFLECTOR ON BOTH EAST AND WEST SIDE. WEST SIDE AREA ~ 6' X 10', EAST SIDE AREA ~ 8' X 10'.
44	A	ABLATIVE AND GRID STEEL ARE MISSING OR DAMAGED IN SEVERAL PLACES: 4' X8' LOWER EAST ON MAIN FLAME DEFLECTOR, ~2' X 4' LOWER WEST SIDE (2 PLACES) MAIN FLAME DEFLECTOR, 1' X 2' UPPER WEST SIDE MAIN FLAME DEFLECTOR, LOWER LIP ON BOTH SIDE FLAME DEFLECTORS.
47	B	FONDUE-FYRE MISSING ALONG EAST BLAST HOLE IMPINGEMENT AREA (~4' X 6')
50	A	• Large sections of ablatives missing beneath both east and west side SRB exhaust holes. • Ablative material at bottom of SRB flame deflector damaged more than usual. Many pieces blown to the north.
53	A	SEVERAL PLACES ON THE MAIN FLAME DEFLECTOR ARE MISSING FONDUE-FYRE. ONE SMALL PIECE OF FONDUE-FYRE IS MISSING FROM LIP OF SSME MAIN FLAME DEFLECTOR.



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Fondu Fyre History From Post-Launch
Data (S6444, S2005, Film Review)

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STS	PAD	DESCRIPTION
55	A	EAST SFD PIECES MISSING AT LOWER LIP AND CRACKS AND HOLES APPROX. 18" . SRB MAIN DEFLECTOR FONDU-FYRE AND GRID TORN AWAY AT EAST SIDE BOTTOM LIP 10' X 20'. 2 TEST PANELS EAST SIDE AND 1 TEST PANEL WEST SIDE BLOWN AWAY. SSME SIDE PIECES (3EA) MISSING
57	B	4' X 6' SECTION OF FONDU-FYRE REFRACTORY CONCRETE IS MISSING
61	B	Minor damage along the lower east lip of main flame deflector. Refractory concrete missing in 2 places (~3' X 3', 1' X 2'). Ablative missing along flame trench wall cap, east side 2 places.
61	B	East work platform grating damaged from fondue hitting underside
62	B	LOWER EAST SRB DEFLECTOR FONDU FYRE BROKEN LOOSE SEVERAL PLACES
65	A	WEST SIDE FLAME DEFLECTOR BOTTOM LIP 8IN. X 6FT. ABLATIVE MISSING AND APPARENT BURN THROUGH CHARRED HORIZONTAL BEAM. 4 BRICKS MISSING FROM NORTH END OF FLAME TRENCH. EAST SIDE FLAME DETECTOR CHIPS 4" X 4" IN 2 PLACES.
68	A	SSME FLAME TRENCH WALL CAP DAMAGED. ABLATIVE MISSING ALONG EAST SIDE APPROX. 15' IN LENGTH. APPROX. 4 FT LONG LOOSE SECTION.
71	A	Photo 16 Rigid object 7" x 2" x .5" ejected from LH SRB exhaust hole. Possible flame trench brick.



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Fondu Fyre History From Post-Launch
Data (S6444, S2005, Film Review)

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STS	PAD	DESCRIPTION
83	A	Pad safety reported material loss and damage to the firewall in the south flame trench. Debris team inspection of the north flame trench showed a 2-foot by 8-inch area of missing firewall material from the flame deflector. Pieces of material were found on the pad apron, the mobile launch platform 0-level and the north flame trench.
84 /94	A	Pad safety reported material loss and damage to the firewall in the south flame trench with pieces of ablative material scattered down the crawlerway to the pad gate
99	A	Debris emanating :From the flame trenches, such as brick and mortar, are commonly transported by the exhaust plumes to outlying acreage areas of the pad without incident to the vehicle. (film review)
111	A	Fondu Fyre 6"x73/4 x4" thick, and numerous smaller chunks
112	B	North Flame trench Deflector, Significant erosion from left and right boosters; fence is damaged with debris at base.
114	B	No findings
115	B	No findings
116	B	Fondu fyre found on pad surface under East side flame deflector shield.



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Fondu Fyre History From Post-Launch
Data (S6444, S2005, Film Review)

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STS	PAD	DESCRIPTION
117	B	<ul style="list-style-type: none"> Large thin pieces scattered within 100' of North throat of Flame Trench. Found on South pad surface almost to slope Several pieces. Found on East Pad Surface. Found South East pad surface Several pieces
118	A	<ul style="list-style-type: none"> Four pieces of Fondu Fyre Found at bottom of South (SSME) Flame Trench. Two (2) small pieces of Fondu Fyre found just South on the East Side Flame Shield.
120	A	<ul style="list-style-type: none"> Large area of missing fondu-fyre from center portion of SRB side of the center flame deflector. Numerous pieces Found laying in flame trench and out towards the end of the concrete pad area. STS-120-K-030: Fondu Fyre pieces found on East Pad Surface South of center flame deflector. Possibly from near mushroom water heads on top of center flame deflector.
121	A	<ul style="list-style-type: none"> K-059: Missing refractory on upper S.W. corner, SRB side, main flame deflector Loose Bricks on East Flame Trench Wall (K-058)
122	A	<ul style="list-style-type: none"> Main flame deflector small piece of fondu fyre was noted near MLP side 1/4 near mount #3 1"X1"X1". Second piece of fondu fyre was found at the perimeter road. Source appears to have come from the fondu fyre overcoating on the flame trench west wall.
123	A	<ul style="list-style-type: none"> Pieces of fondu fyre found in several locations all on West side from very South end of pad surface, next to RSS truck, just South of elevator.
124	A	<ul style="list-style-type: none"> Two pieces of fondu fyre found out side of the flame trench on West apron. Integrated IFA 2 taken for massive brick liberation.



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Dent on MLP Underside

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- A reliable USA Structures Engineer recalls a large dent appearing on the underside of MLP-3 approximately 6 years ago after a launch. The dent originally had rust markings corresponding to the pattern of Fondu Fyre grid steel.
- No documentation was found recording the event at that time.
- The MLP has since been repainted, but still has the large dent.



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Dent on MLP Underside

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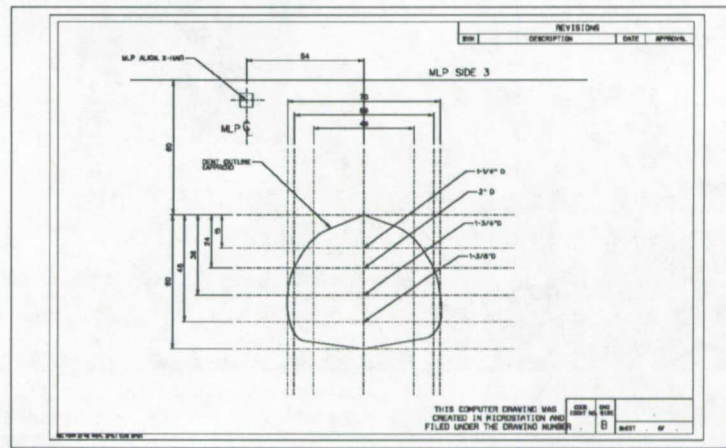
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Dent on MLP Underside

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Fondue Fyre on MLP deck (STS-83)

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- The STS-83 Post Launch Pad Debris Inspection Report has the following entry:
 - "Pad Safety reported material loss and damage to the firewall in the south flame trench. Debris Team inspection of the north flame trench showed a 2 foot by 8 inch area missing firewall material from the flame deflector. Pieces of material were found on the Pad apron, the Mobile Launch Platform 0 level and the north flame trench."
- Corporate memory of this walk-down yielded no information, and the associated photo documentation no longer exists.
- Red Herring:
 - Years ago Fondue Fyre was used to seal the base of the TSMs on the MLP zero level. It was hoped that would explain this report.
 - Research showed that MLP-1 and MLP-2 used Fondue Fyre on the TSMs. STS-83 used MLP-3, which came already modified and did not require the seal.
- Conclusion: Cannot corroborate nor discount the possibility that Fondue Fyre was ejected to MLP deck on STS-83.



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Fondue Fyre Classification Background

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- PRCB action S061954A to the elements was to characterize critical debris in the launch environment.
- Launch & Landing defined the critical debris zone as "in and around the zero level of the MLP and above".
- Fondue Fyre is classified as "**Unexpected**" since it does not appear above the MLP "by design". It is designed to abrade/erode and remain below MLP deck.
- However, Fondue Fyre was still addressed at the ERB, SICB, and PRCB levels due to the uncertainty involved in the transport potential. KSC requested CFD analysis to verify that Fondue Fyre could not damage the vehicle during launch. The 12/17/04 SICB directed that a CFD analysis would not be done (at that time).
- K-IFAs still taken for Fondue Fyre found on Pad surface after launch to maintain awareness and track trends.



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Efforts to Improve Refractory

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Over the Years, KSC has made many efforts to mitigate Fondue Fyre liberation:

- Consultations with manufacturer (Pryor Giggey) to improve application process.
 - Spray on instead of trowel on application.
 - Water content of mix is closely monitored.
 - Nelson studs and grid steel used to add strength.
- Experiments with different materials.
 - Fondue Frag (with metal pieces) was tried unsuccessfully.
- Different vendors were approached for alternatives.
- University professor Dr. Schimler conducted review of specifications and refractory research.

Improvements in the application process have resulted in fewer and smaller incidences of liberation.



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Summary of Historical Data

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- There is a long history of Fondue Fyre liberation in the flame trenches, including the SRB main flame deflectors, side deflectors, and SSME flame deflector.
- Some early liberations were of significant size, and even included missing grid steel.
- There is evidence that Fondue Fyre has hit the underside of the MLP in the past.
- The STS-83 record of Fondue Fyre on the MLP deck cannot be corroborated, nor can it be discounted.
- Improvements in Fondue Fyre application and materials have resulted in reduced liberation.



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Recommendation

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- Recommend approval to present this data to the 8/13/08 DIG for closure of action.



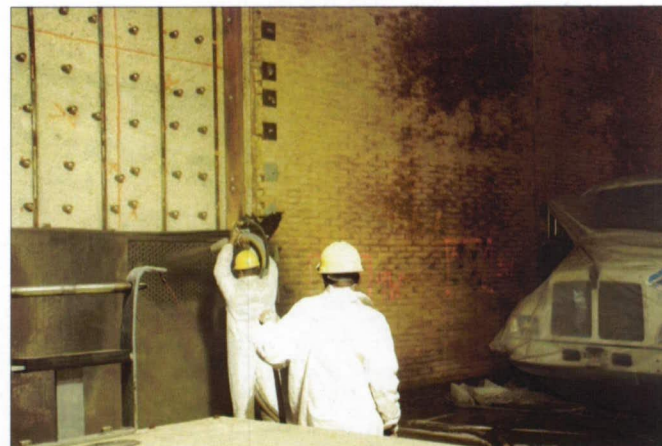
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Backup

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Request for Information II

The following questions were prepared to collect more information for the current research project "Flame Deflector Protection System for Corrosion Control." Also, there are questions about the answers provided by NASA in the previous *Request for Information I*.

1. Clarification of Scope of Application of New Protection System

- a. Please specify facilities/areas and their quantities for the application of new protection system.
- b. How many flame deflectors do you have at each launch complex?
- c. Do you have movable deflectors? If yes, are they also in the scope of application?

2. Historical Data

The research team plans to analyze historical data on shuttle launches and repair/maintenance expenditures in order to quantify the relationships between launches and minor and major repairs. For this task, please provide the relevant historical data below.

- a. History of shuttle launches for the last 45 years. Please include the following information for each launch.
 - i. Date of launch
 - ii. Classification of locations, i.e., 39A, 39B, etc.
 - iii. Type of launch vehicle, if not shuttle
- b. Historical record of contracts for the last 45 years, for the repair projects performed by outside contractors. Please include the following information for each repair project.
 - i. Date of contract
 - ii. Type of contract (fixed price or cost plus fee)
 - iii. Project cost
 - iv. Project duration
 - v. Classification of facilities or areas repaired
 - Refractory concrete on flame deflector
 - Flame deflector steel structure
 - Walls and floor of flame trench
- c. History of internal work orders for the last 45 years, for maintenance and repairs not performed by outside contractors. please include the following information for each work order.
 - i. Date
 - ii. Project cost
 - iii. Project duration
 - iv. Classification of facilities or areas repaired

Request for Information

- Refractory concrete on flame deflector
- Flame deflector steel structure
- Walls and floor of flame trench

3. Other Questions

- a. The research team is requesting a copy of the "OMI/Job Plan" cited in the NASA response to RFI I.
- b. Is it possible to obtain a copy of the plan for future launches? If yes, please provide a copy and the last anticipated shuttle launch. Also, is there a plan on the anticipated number of launches for the new vehicles? If so, please provide a general number.
- c. Can we expect a same number of launches at each complex on average in the future? In terms of NASA's use of the two launch complexes 39A and 39B, are there any differences or preferences between them with respect to future launches?